CLINICS 2009;64(8):757-62

CLINICAL SCIENCE

THE VALUE OF CALCANEAL BONE MASS MEASUREMENT USING A DUAL X-RAY LASER CALSCAN DEVICE IN RISK SCREENING FOR OSTEOPOROSIS

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doi: 10.1590/S1807-59322009000800008

Kayalar G, Cevikol A, Yavuzer G, Sanisoglu Y, Cakci A, Arası T. The value of calcaneal bone mass measurement using a Dual X-Ray Laser calscan device in risk screening for osteoporosis. Clinics. 2009;64(8):757-62.

OBJECTIVE: To evaluate how bone mineral density in the calcaneus measured by a dual energy X-ray laser (DXL) correlates with bone mineral density in the spine and hip in Turkish women over 40 years of age and to determine whether calcaneal dual energy X-ray laser variables are associated with clinical risk factors to the same extent as axial bone mineral density measurements obtained using dual energy x-ray absorbtiometry (DXA).
MATERIALS AND METHODS: A total of 2,884 Turkish women, aged 40-90 years, living in Ankara were randomly selected. Calcaneal bone mineral density was evaluated using a dual energy X-ray laser Calscan device. Subjects exhibiting a calcaneal dual energy X-ray laser T- score ≤-2.5 received a referral for DXA of the spine and hip. Besides dual energy X-ray laser measurements, all subjects were questioned about their medical history and the most relevant risk factors for osteoporosis.
RESULTS: Using a T-score threshold of –2.5, which is recommended by the World Health Organization (WHO), dual energy X-ray laser calcaneal measurements showed that 13% of the subjects had osteoporosis, while another 56% had osteopenia. The mean calcaneal dual energy X-ray laser T-score of postmenopausal subjects who were smokers with a positive history of fracture, hormone replacement therapy (HRT), covered dressing style, lower educational level, no regular exercise habits, and low tea consumption was significantly lower than that obtained for the other group ($p<0.05$). A significant correlation was observed between the calcaneal dual energy X-ray laser T-score and age ($r=-0.465$, $p=0.001$), body mass index (BMI) ($r=0.223$, $p=0.001$), number of live births ($r=-0.229$, $p=0.001$), breast feeding time ($r=-0.064$, $p=0.001$), and age at menarche ($r=-0.050$, $p=0.008$). The correlations between calcaneal DXL and DXA T-scores ($r=0.340$, $p=0.001$) and calcaneal DXL and DXA Z-scores ($r=0.360$, $p=0.001$) at the spine, and calcaneal DXL and DXA T- scores ($r=0.28$, $p=0.001$) and calcaneal DXL and DXA Z-scores ($r=0.33$, $p=0.001$) at the femoral neck were statistically significant.
CONCLUSION: Bone mineral density measurements in the calcaneus using a dual energy X-ray laser are valuable for screening Turkish women over 40 years of age for the risk of osteoporosis.

KEYWORDS: DXL; DXA; Osteoporosis; Osteoporosis risk factors.

INTRODUCTION

Screening for osteoporosis is mandatory given that it is a common disease associated with high morbidity, mortality, and cost. Furthermore, accurate and safe diagnostic tests are available, and treatment is effective.[1,2] Early diagnosis and quantification of bone loss and fracture risk have become more important due to the availability of therapies that can slow or even reverse the progression of osteoporosis. Low bone mass is the strongest predictor of low and moderate energy fracture risk.[3] Thus, timely evaluation of bone mass is a recognized criterion in selecting patients for pharmacologic intervention. The demonstration of microarchitectural disruption requires a bone biopsy, which is rarely performed for suspected osteoporosis and never for screening purposes.

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Received for publication on January 20, 2009
Accepted for publicaiton on May 07, 2009

Measurements of biochemical markers of bone turnover are not useful for screening but may complement measurements of bone density. Bone density measurements (BMD) are the most common method of screening for osteoporosis; however, the bone densitometers used for spine and hip measurements are rather expensive and require quite a lot of space and skilled personnel. Still, these measurements are indicated whenever the results will help guide the therapeutic decision-making process for a patient. Therefore, a device that is small, less expensive, and easy to use for unskilled personnel would be of value in screening for osteoporosis.

Measurement of bone mass by dual energy x-ray absorbtiometry (DXA) is the most frequently applied technology to determine the individual risk of sustaining a fracture. Conventional DXA technology assumes a two-component tissue model consisting of only bone mineral and soft tissue. The absorption properties of adipose tissue, however, are significantly different from those of both bone mineral and lean soft tissue. This gives rise to accuracy errors between 10 and 20% using conventional DXA technology.[4] A more realistic model of tissues is a three-component model consisting of bone mineral, lean soft tissue, and adipose tissue. The volume of marrow adipose tissue increases with age and is particularly large in patients with osteoporosis.[5] To measure the bone mineral content without the influence of adipose tissue both inside and outside the measured bone, three different measured quantities must be used. Dual energy X-ray laser measurement (DXL) technology was developed with this in mind and employs two X-ray energies in combination with laser measurements of the object thickness to determine all three tissue components. Since the total linear thickness of the object being measured is composed of the individual thickness of the bone mineral, lean soft tissue, and adipose tissue, it is possible to combine the thickness measurement with the two X-ray measurements and obtain a unique solution for the three different components at the measurement site.[6]

In clinical practice, a BMD measurement is only useful when the fracture risk can be estimated from the measurement. Several studies have found that the relative risk of all fractures estimated from heel BMD measurements is similar to that obtained from DXA measurements in the hip and lumbar spine.[7] For vertebral fracture prediction, heel BMD measurements, such as DXL Calscan, are similar to those made in the spine and better than those made in the forearm and hip.[6]

The relationship between lifestyle and environmental risk factors and either bone density or fracture incidence has been addressed in a number of epidemiological studies.[8] In most of these studies, the bone mass was evaluated by DXA at the spine or the hip.[9] DXL could substantially increase accessibility to a reliable bone osteoporosis risk evaluation, but little is known regarding the relationship between DXL and risk factors.

The objective of this study was two-fold: 1) to evaluate how BMD in the calcaneus measured using a Demetech, DXL Calscan device correlates with BMD in the spine and hip in Turkish women over 40 years of age; 2) to determine whether calcaneal DXL variables are associated with clinical risk factors to the same extent as axial BMD measurements obtained using DXA.

Subjects and Methods

A total of 2,884 Turkish women, aged 40-90 years, living in Ankara were randomly selected. General practitioners were asked to contact all of the selected subjects and refer them to the study center without any exclusion criteria. All subjects agreed to participate.

Calcaneal BMD was evaluated using a Demetech (Demetech AB, Stockholm, Sweden) DXL Calscan device. The *in vivo* and *in vitro* precision of DXL Calscan are 1.2% and 0.5%, respectively.[6] Subjects with calcaneal DXL T-scores ≤ -2.5SD received a referral for DXA of the spine and hip using a Hologic QDR 2000 (Hologic Inc. Waltham, Massachusetts, USA). The coefficient of variation for the Hologic QDR 2000 was 1.0% for the spine.

In addition to the DXL measurements, all subjects were questioned regarding their medical history and the most relevant risk factors for osteoporosis considered to be predictors of bone mass, according to previously published clinical and epidemiologic studies.[1] The questionnaire for risk factors was presented in table 1.

Statistical analysis was performed using SPSS 9.0 (SPSS Inc, Chicago, IL, USA). The difference in calcaneal DXL T-scores among categorical variables (e.g., menopausal status, history of HRT, fracture history and family fracture history, regular exercise, dressing style, educational level, low calcium intake, smoking, tea, coffee, and alcohol consumption) was assessed using a T-test for independent samples or one-way ANOVA according to the number of groups. The correlation between calcaneal DXL T-scores and continuous variables (e.g., age, BMI, age at menarche and menopause, number of live birth, breast feeding time) and between calcaneal DXL T- and Z-scores versus DXA T- and Z-scores was assessed using a Pearson correlation coefficient. All results were considered significant at $p<0.05$.

RESULTS

The continuous and categorical osteoporosis risk factors evaluated and their association with the calcaneal

Table 1 - Questionnaire for risk factors

Age (years)	
Height (cm)	
Body weight (kg)	
Age at menarche (years)	
Number of live births	
Breast feeding time (years)	
Menopausal status	
Use of hormone replacement therapy	
Educational level	Illiterate / reader-writer / primary school / high school / university
Dressing style	Modern / covered
Daily consumption	Milk / yogurt / cheese
Tea / coffee / alcohol	
Smoking	
Exercise habits	Walking > 30 min / day
Chronic diseases	Diabetes mellitus / thyroid disease / hypertension
Low energy fracture history	
Familial history of fracture	
Relatives with kyphosis	
Previous level of knowledge about osteoporosis	

DXL T-score are shown in Tables 2 and 3. Mean(SD) weight and height of the study group were 74.61(11.97) kg and 159(0.06) cm, respectively. Based on the calcaneal DXL T-score, 13% of the subjects had osteoporosis, and 56% had osteopenia. More than half of the subjects were postmenopausal, without a history of HRT, regular exercise, or fracture. Eighty percent of the subjects were housewives with a very low education level. The dressing style was covered for 85% of the subjects, and approximately 2/3 of the subjects were obese with a short height. The mean body mass index was 29.5 kg/m². Fifty-five percent of the

Table 2 - Continuous variables of osteoporosis risk factors and their association with the DXL T–score

N=2884	mean±SD	r	p
Age (years)	53.4± 9.1	-0.465	0.001
BMI (kg/m2)	29.5± 6.3	0.223	0.001
Age at menarche (years)	13.8±1.4	-0.050	0.008
Age at menopause (years)	45.8±5.59	-0.001	0.956
Number of live births	3.8±2.05	-0.229	0.001
Breast feeding time (years)	1.7±0.54	-0.064	0.001
BMD (heel –DXL) (g/cm2)	0.393±0.07	-	-
T-score (heel –DXL)	-1.5±1.1	-	-
Heel thickness (mm)	55.6±4.9	-	-

Table 3 - Categorical variables of osteoporosis risk factors and differences between groups in terms of the DXL T-score (values are presented as mean±SD for the DXL T-score)

	%	DXL T- score	t	p
Post-menopausal	62%	-1.7±0.91	-2.6	0.009
Pre-menopausal	38%	-1.6±0.85		
Post-menopausal HRT (+)	23%	-1.6±0.79	2.0	0.043
Post-menopausal HRT (-)	67%	-1.7±0.93		
Fracture history (+)	18%	-1.7±0.50	-4.5	0.001
Fracture history (-)	82%	-1.5±0.91		
Family history of fracture (+)	24%	-1.5±0.89	1.92	0.054
Family history of fracture (-)	76%	-1.5±0.92		
Covered dressing style	85%	-1.5±0.91	-4.25	0.001
Modern dressing style	15%	-1.3±0.85		
Illiterate	5%	-1.8±0.91	3.2	0.001
Reader-writer	11%	-1.6±1.11		
Primary school	54%	-1.4±0.82		
High school	30%	-1.3±0.84		
Regular exercise ≥ 30min/day (+)	42%	-1.4±0.84	-4.7	0.001
Regular exercise ≥ 30min/day (-)	58%	-1.6±0.95		
Tea consumption ≥ 4cups/day (+)	74%	-1.4±0.90	4.9	0.001
Tea consumption ≥ 4cups/day (-)	26%	-1.6±0.92		
Coffee consumption ≥ 4cups/day (+)	16%	-1.5±0.98	3.6	0.001
Coffee consumption ≥ 4cups/day (-)	84%	-1.3±0.92		
Smoking ≥ 4/day for 2 years (+)	14%	-1.5±0.92	4.2	0.001
Smoking ≥ 4/day for 2 years (-)	86%	-1.3±0.81		

subjects reported a daily calcium intake of less than 500 mg/day, and the amount of daily tea consumption, but not coffee and alcohol, was very high. Among the subjects, only 14% were smokers and the main chronic diseases reported were hypertension, diabetes mellitus, and thyroid diseases. Approximately one-fifth of the subjects had a history of low energy fracture. A positive family history for fractures was infrequent (24%), and most subjects had no relatives with kyphosis. Most of the participants had not previously heard of osteoporosis and had no information about it. A comparison of the groups in terms of the calcaneal DXL T-score is presented in Table 3. The mean calcaneal DXL T-score of the postmenopausal subjects who were smokers with a history of fracture, HRT, covered dressing style, lower educational level, no regular exercise habit, and low tea consumption was significantly lower than obtained for the other group ($p<0.05$). The association between osteoporosis risk factors and the calcaneal DXL T-score is shown in Table 2. A moderate correlation was observed between the calcaneal DXL T-score and age and BMI. A weak but significant correlation was found between the calcaneal DXL T-score and age at menarche**,** number of live births, and breast feeding time. The correlations between calcaneal DXL T- and Z-scores and between DXA T- and Z-scores at the spine and femoral neck are shown in Table 4. Calcaneal DXL T- and Z-scores were weakly but significantly correlated with DXA T- and Z-scores at the spine and femoral neck.

Table 4 - Correlation between DXL T- and Z- scores, and DXA T- and Z-scores at the spine and femoral neck (r=Pearson correlation coefficient)

N=373	mean±SD	r	p
DXL T-Score	-2.9±0.62	0.34	0.001
DXA Spine T-Score	-1.8±0.92		
DXL Z-Score	-1.8±0.52	0.36	0.001
DXA Spine Z-Score	-0.49±0.93		
DXL T-Score	-2.9±0.62	0.28	0.001
DXA Femoral Neck T-Score	-2.1±0.93		
DXL Z-Score	-1.8±0.52	0.33	0.001
DXA Femoral Neck Z-Score	-0.5±0.96		

DISCUSSION

In the present study, we evaluated 2,884 Turkish women between 40 and 90 years of age with regard to osteoporotic risk factors and DXL measurements. Using a T-score threshold of –2.5 (WHO), DXL heel measurements showed that 13% of the subjects had osteoporosis, and another 56% had osteopenia. These percentages were within the expected range based on National Osteoporosis Foundation reports[11] and previous epidemiological studies performed in Turkey.[12] DXL data were correlated with previously published relevant risk factors for osteoporosis as well as DXA data in the subgroup of subjects with osteoporosis.

DXL has been introduced as a novel method to assess skeletal status with the advantages of being easy to use, a relatively short examination time, and sufficiently good reproducibility.[13,14] Its relationship with other devices was shown to be good, and its relationship with other sites of the skeleton excellent. Martini et al. evaluated calcaneal BMD (DXL) and lumbar spine BMD (DXA) in 40 postmenopausal women and reported a high correlation between DXL BMD and L2-L4 BMD, in addition to the diagnostic accuracy of DXL.[15] Kullenberg and co-workers compared the prevalence of osteoporosis using a T-score threshold of –2.5 for calcaneal measurements by DXL technology to the prevalence using DXA measurements at the femoral neck, spine, and forearm[6]. The prevalence of osteoporosis for women aged 50 years or older was 28% for DXL measurements of the calcaneus and 30, 22, and 32% for DXA measurements of the lumbar spine, femoral neck, and forearm, respectively. The DXL Calscan sensitivity (80% for osteoporosis and 82% for osteopenia) and specificity (82% for osteoporosis and 89% for osteopenia) were very high. They reported the fracture prediction capability of DXL Calscan to be similar to or better than the measurements at the hip, spine, or radius.[6] Consistent with previous studies,[6-13-15] the present study revealed a significant correlation between calcaneal DXL T-scores and DXA T-scores at the femoral neck and spine. The lower power of the correlation obtained in this study compared to previous studies could be contributed to differences in the sociodemographic characteristics of the study populations. DXL measurements at the calcaneus showed a similar pattern as axial measurements and hip measurements in terms of T-scores, and thus may be used equally well for diagnosis as axial DXA.

The relationship between specific osteoporosis risk factors and bone mass has been extensively investigated in several epidemiologic and observational studies.[8-9] The most commonly cited risk factors for osteoporosis are prior fragility fracture, aging, family history of osteoporosis, low body weight, physical inactivity, early menopause, smoking, high caffeine intake, and low calcium intake.[1-16-17] Age at menarche, number of live births, and breast feeding time have also been identified as minor but significant predictors and determinants of bone density and strength.[18-20] It is clear that DXA-based measurements of BMD are significantly lower in individuals with positive risk factors for osteoporosis than in those without. In most previous studies, bone mass was evaluated by DXA at the spine or at

the hip; however, little is known regarding the relationship between DXL and risk factors for osteoporosis.[21-26] The findings of this study revealed that calcaneal DXL variables are associated with clinical osteoporosis risk factors to the same extent that are axial BMD measurements obtained using DXA. In spite of the statistical significance, the power of correlation between DXL and risk factors was weak, supporting the idea of using BMD measurements together with other risk factors for fracture as the basis for treatment decisions. It has been shown that the use of BMD in the assessment of risk has high specificity but low sensitivity, indicating that many fractures will still occur in individuals considered to be at low risk.[1] This is one of the reasons why BMD alone cannot be used for population screening. The use of independent risk factors in addition to BMD improves the sensitivity (detection rate of individuals) without a loss of specificity.[3]

The relationship between osteoporotic risk factors and DXL bone values has previously been studied only in relatively small groups of young subjects. In these studies, good correlations between the calcaneal DXL T-score and body weight, muscle strength, physical endurance, menstrual disturbances, and smoking were found.[21-26] To our knowledge, this is the first study to assess over 2,500 women (40-90 years of age) to investigate the value of calcaneal DXL measurements in osteoporosis screening. Our findings revealed a significant negative association between the calcaneal DXL T-score and age, number of live births, breast feeding time, age at menarche, and menopause. BMI and the calcaneal DXL T-score, however, were positively associated. Postmenopausal women with a history of HRT, fracture, smoking, and higher coffee consumption demonstrated significantly lower calcaneal DXL T-scores. Women with a higher educational level, modern dressing style, regular exercise habits, and daily tea consumption of more than four cups seemed to have significantly better calcaneal DXL T-scores. The presence of an association between osteoporosis risk factors and the calcaneal DXL T-score in this study was similar to previous Turkish epidemiological studies of osteoporosis carried out using DXA.[27-29]

This study revealed that BMD measurements of the calcaneus by a Demetech, DXL Calscan device were easy to obtain, with a short examination time, and showed a weak to moderate but significant correlation with DXA for osteoporotic subjects. Our data also suggest that calcaneal DXL variables are associated with clinical risk factors to the same extent as axial BMD measurements obtained using DXA. We conclude that the DXL Calscan device is valuable for screening Turkish women over 40 years of age for the risk of osteoporosis. Questioning regarding relevant osteoporosis risk factors may increase the possibility of detecting subjects with a high risk of fracture. Further prospective studies with calcaneal DXL are needed to make intelligent treatment decisions and to monitor the effects of treatment when osteoporosis risk factors are present.

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